both charts, 24 on Neison's and not on Prof. Pickering's, while 11 were found on Prof. Pickering's and not recorded by Neison. With higher powers, all Neison's, except two, were discovered, and, in addition, several other small ones. Just about the region of Bessel a change seems to have taken place since Neison made his map, for there are one or two cases in which the crater-pits picked out by him for reference are now not the most conspicuous objects, there being several others far more prominent in the immediate vicinity. The floor of Plato also has been carefully scrutinized, and several of what were then more or less distinct luminous points are now either invisible or barely so, while one large crater was seen where previously none was recorded. Whether a real change has taken place in these parts of the moon's surface, or whether the antecedent observations were sufficiently accurate, is a matter of doubt, and it is for future observers to determine this. But now, as Prof. Pickering says, "that we are able to study the smaller lunar craters to advantage, and so many changes are noted, it does not seem as if the same cause (the mere action of sunlight) can have affected so many of them in the same way, nor does it seem as if all the changes noted can be due to erroneous delineation."

CATALOGUE OF NEBULÆ.—In *Astronomische Nachrichten*, No. 3094, the Catalogue No. 10 of nebulæ discovered at the Warner Observatory by Swift is inserted. The number included, which generally consists of one hundred, amounts here to sixty, the reason being that owing to the increasing number of electric street lights these faint objects are rendered invisible by the illumination of the atmosphere.

GEOGRAPHICAL NOTES.

DR. HENRY SCHLICHTER contributes a valuable epitome of our knowledge of the pygmies of Africa to the June number of the *Scottish Geographical Magazine*. He divides the dwarf tribes hitherto reported into four great groups, according to the regions they inhabit, recognizing, however, the probability of further exploration revealing connecting links between them. The first group, or dwarfs of West Africa, includes the Obongo, Akoa, and Babongo, which vary between 4 and 5 feet in height. The second, or Central African group, contains the Akka, Wambutti, and Batua, of even smaller stature, inhabiting the Congo Basin, scattered amongst Bantu tribes. The third group is that of the East African pygmies, whose existence east of the Nile and south of Kaffa was reported as early as 1826; but they are still little known. The fourth group, those dwelling south of the Congo basin, is relegated to another paper.

ORDNANCE MAPS of Great Britain are at last coming prominently before the public. Although not likely to gratify those engaged in producing the sheets, popular attention will doubtless result in direct and early benefit to cartography and even to geography at large. A Parliamentary Committee, on which scientific geographers are well represented, has the whole matter under investigation, and the energetic criticisms of Mr. Crook, which have so long passed unheeded, are now receiving further expression in a series of articles in the *Times*. The particular object of attack is the new quarter-inch outline map of England and Wales, a map put forward by the Survey with some natural diffidence, for it is founded on measurements the most recent of which were made twenty years ago, and the earliest at the very beginning of the century. The delineation of the country, in consequence of the want of subsequent revision, resembles a star-chart, in so far as it represents each point as it existed at some different time in the past. Unlike a star-chart, however, the quarter-inch map of England is of no scientific and little practical value. The more thoroughly this matter is investigated, and the more speedily it is rectified, the better will it be for the Survey officers, whose magnificent triangulations and unparalleled accuracy of observation have made the mapping of the British Islands a model for the world to admire. It is high time that steps be taken for regular periodical revision of all Ordnance maps, and for publication in a form comparable with that of the Staff maps of France and other Continental nations.

AN appreciative article on the late Prof. Freeman and his services to geography appears in the June number of the *Proceedings* of the Royal Geographical Society. Freeman's most important service was to demonstrate that the physical geography of a region largely determines the political geography of the countries upon it, and that a knowledge of past geographical conditions is essential in order to understand history.

THE report of an expedition to Argentine Tierra del Fuego by Señor Julio Popper has been recently published by the Argentine Geographical Society. The region in question is the eastern half of Tierra del Fuego, the geological structure of which is mainly Tertiary rocks much disintegrated; the coast line is little indented, with few harbours, the sea shallow and abounding in sand-banks, while the climate, dominated by the warm Brazil current, is equable and moist. The south coast bordering the Beagle Channel is rugged, rocky, and under the climatic influence of the cold Antarctic drift. The tribes inhabiting the island of Tierra del Fuego proper are the Ona (compare NATURE, xlv. 577), who are described as of fine physique, resembling the Indians of North America, and susceptible of civilization. Indeed, Señor Popper contrasts their magnanimous and forgiving character very favourably with the unreasoning cruelty of the white gold-seekers who have invaded their territory, yet the Onas are said to be inveterate thieves. The map accompanying this report is covered with new names for features already designated, and it can hardly be expected that these will be accepted by European geographers.

MRS. BISHOP (Miss Bird) read an interesting paper on her recent journey to Little Tibet, before the London branch of the Royal Scottish Geographical Society, on May 31, the Duke of Argyll presiding. Lady travellers are not encouraged to describe their expeditions to the Royal Geographical Society, and as the British Association, which receives communications from men and women on an equal footing, cannot meet in London, this opportunity for a metropolitan audience to hear at first hand the account of an adventurous journey, and the sympathetic estimate of the inhabitants of a little-known region, by a woman of Mrs. Bishop's tried courage and trained observing powers was naturally taken advantage of to the utmost.

MICRO-ORGANISMS IN THEIR RELATION TO CHEMICAL CHANGE.[1]

ALMOST exactly on this day twenty-two years ago the subject of micro-organisms was introduced to the audience of the Royal Institution in one of those charming discourses, which so many of us well know were always to be heard from Dr. Tyndall. The title of his discourse on that occasion was "Dust and Disease," and its contents should be studied by all interested in this departure of science, forming, as it does, a part of the classical literature of the subject in which it marks the commencement of a new epoch.

It has probably rarely, if ever, happened before, that in so short a period as twenty-two years any science has undergone such a marvellous advance, such a many-sided development, as that which has taken place in the case of bacteriology, the science which is devoted to the study of those low forms of life which we group together under the name of *micro organisms*. This advance has been made through the ungrudging expenditure of self-denying labour by a great body of earnest workers of nearly every nationality. The subject is, indeed, one calculated to draw forth interest and enthusiasm, for the problems involved are not only of high scientific importance, but are also of incalculable moment to mankind, and, indeed, to the entire living creation.

The great impetus which this new science received at its outset was imparted by Pasteur, who has not only laid the foundations, but has also added, and is still adding, so much to the superstructure of its many mansions.

The side of bacteriology with which the general public is most commonly brought in contact is that which relates to disease, but of this I propose saying absolutely nothing to-night. It has been dealt with by others in this place, and notably by my friend Dr. Klein.

There is a second side of bacteriology which has also a special interest for at least a portion of the public, in consequence of the invaluable assistance which it has afforded to some sections of the industrial world. Indeed, chronologically, this industrial department of bacteriology was the first which claimed attention, for the growers of wine, the brewers of beer, and the manufacturers of fermented liquors of all kinds from the highest antiquity have been practical bacteriologists, of the same spontaneous order, it is true, as M. Jourdain was an unconscious author of prose. It was Pasteur also who first infused science into the operations of the wine-vat and the fermenting-tun, by his classical "Études sur la Bière et sur le Vin." It was he who first showed that the normal work of the brewery was accomplished by particular forms of micro-organisms, known as yeast, and that the frequent failures to produce beer or wine of the desired quality was occasioned by the presence of foreign forms of micro-organisms giving rise to acidity and other undesirable changes in these beverages.

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[1] Friday Evening Discourse, delivered by Prof. Percy F. Frankland F.R.S., at the Royal Institution of Great Britain, on February 19, 1892.

In these researches of Pasteur's on beer and wine, we are almost for the first time brought face to face with the precise nature of some of the chemical changes which micro-organisms bring about. The time-honoured vinous fermentation of sugar, the products of which had been valued and indulged in by man even from the days of Noah, is for the first time so accurately studied as to be definable almost with the precision of a chemical equation.

Similar attention was also given by Pasteur to some of the other micro-organisms which deteriorate the quality of the beer—thus more especially to the bacterium which causes the *acetic* or vinegar fermentation, which is a process of *oxidation*, transforming alcohol into vinegar; to the bacillus inducing the *lactic* fermentation, which is a process of *decomposition*, in which sugar yields lactic acid; as well as to that which brings about the *butyric* fermentation, a process of *reduction*, in which butyric acid is formed.

These are the foundations and scaffolding on which subsequent investigators of the phenomena of fermentation have laboured. Thus, making use of more refined methods than those which were at the disposal of Pasteur, Christian Hansen, of Copenhagen, has enormously extended our knowledge of the alcohol-producing organisms or yeasts; he has shown that there are a number of distinct forms, differing indeed but little amongst themselves in shape, but possessing very distinct properties, more especially in respect of the nature of certain minute quantities of secondary products to which they give rise, and which are highly important as giving particular characters to the beers produced. Hansen has shown how these various kinds of yeast may be grown or cultivated in a state of purity even on the industrial scale, and has in this manner revolutionized the practice of brewing on the Continent. For during the past few years these pure yeasts, each endowed with particular qualities, have been grown with scrupulous care in laboratories equipped expressly for this purpose, and these pure growths are thence despatched to breweries in all parts of the world, particular yeasts being provided for the production of particular varieties of beer. In this manner scientific accuracy and the certainty of success are introduced into an industry in which before much was a matter of chance, and in which nearly everything was subordinated to tradition and blind empiricism.

The Bacteria connected with the Soil.

It is, however, with regard to the bacteria connected with other industries than those of alcoholic fermentation that our knowledge has particularly advanced during the last few years. Thus some of the most important phenomena in agriculture have recently received a most remarkable elucidation through the study of bacteria.

Scientific agriculturists are generally agreed that one of the most important plant-foods in the soil is *nitric acid;* indeed they inform us that if a soil were utterly destitute of this material it would be incapable of growing the barest pretence of a crop, *either of corn, or of roots, or of grass*, even if the soil were in other respects of the most superb texture, however favourably it might be situated, however well drained, tilled, and supplied with the purely mineral ingredients of plant-food, such as *potash, lime*, and *phosphoric acid*.

Yet, notwithstanding the commanding importance of this substance nitric acid to vegetation, it is present in ordinary fertile soils in but little more than homœopathic doses.

These facts are gathered from those grand experiments which have during the past half-century been going on at Rothamsted under the direction of Sir John Lawes and Dr. Gilbert, and which have rendered the Hertfordshire farm a luminous centre of the whole agricultural world.

From these experiments it appears that sometimes there is in fertile soil under 1 part, and often under 10 parts, of nitrogen as nitrate per million of soil.

Indeed, in order to detect and estimate these minute quantities, the most refined methods of chemical analysis have to be called into requisition. [Demonstration of the presence of nitric acid in soil by diphenylamine test.]

Now the cause of such minute quantities only of nitric acid being found in soils is due partly to this material being washed away by the rain, and partly to its being so eagerly taken up by plants for the purposes of nutrition; for it has long been known that by suitable means the quantity can be enormously increased if no vegetation is maintained, and the ground properly protected from rain. The soil, in fact, under ordinary circumstances, continuously generates this nitric acid from the various nitrogenous manures which are applied to it, and it is in the form of nitric acid that the nitrogen of manures principally gains access as nutriment to the plant.

It was in the year 1877 that two French chemists, Schlœsing and Müntz, showed that this power of soils to convert the nitrogen of nitrogenous substances into nitric acid was due to low forms of life—to micro-organisms or bacteria. The proof which they furnished of this statement was of a very simple character, and consisted essentially in demonstrating that this production of nitric acid, or process of *nitrification*, as it is generally called, is promptly inhibited or brought to a standstill by all those materials which have the property of destroying micro-organisms, and which we call *antiseptics;* whilst similarly the process is stopped by heat and other influences which are known to be fatal to life in general.

These results of Schlœsing and Müntz were confirmed and greatly extended in this country by Mr. Warington and Dr. Munro, but although the vital nature of the process was fully established, little practical advance was until recently made in the identification or isolation of the particular bacteria responsible for this remarkable and invaluable transformation.

In 1886, however, a very important step was made by Dr. Munro, who showed that this process of nitrification could take place in solutions practically destitute of organic matter, or, in other words, that the vital activity of the bacteria of nitrification could be maintained without nutriment of an organic nature.

In 1885, I had myself already established the fact that some micro-organisms can actually undergo enormous multiplication in ordinary distilled water:—

Multiplication of Micro-organisms in Distilled Water.[1]

Hours after introduction of micro-organisms.	Number of micro-organisms found in 1 c.c. of water.
0	1,073
6	6,028
24	7,262
48	48,100

In taking up the subject of nitrification in conjunction with my wife in the autumn of 1886, I determined to avail myself of this remarkable property of the nitrifying organisms to grow in the absence of organic matter, thinking that in this way it would be possible to achieve a separation of the nitrifying organisms from other forms which can only grow if organic food materials are supplied to them.

Proceeding on these lines, we have carried on the process of nitrification over a period of upwards of four years without the nitrifying organisms being supplied with any organic food materials whatsoever:—

Composition of Solution employed for Nitrification.

Ammonium chloride	·5 grm.	In 1000 c.c. of distilled water.
Potassium phosphate	·1 „	
Magnesium sulphate	·02 „	
Calcium chloride	·01 „	
Calcium carbonate	5·0 „	

In a solution of this composition the process of nitrification was carried on over a period of upwards of four years, as indicated in the table on p. 137.

In carrying on this series of experiments it was soon evident that although a number of forms foreign to the nitrification process were being eliminated, there were still some remaining alongside of the nitrifying organisms, or, in other words, that a pure culture of the nitrifying organisms had not been obtained. From various considerations, however, we came to the conclusion that the nitrifying organisms probably differed from the other forms which were still present along with them in being unable to grow on the common cultivating medium employed by bacteriologists, and known as gelatin-peptone.

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[1] Proc. Roy. Soc., 188

Experiments on Continuous Nitrification in Mineral Solutions.

Generation	Date of inoculation.	Quantity taken for inoculation.	Date when nitrification first observed.
I.	9 5 1887	Original garden soil	20 5 1887
II.	25 6 1887	3 needle-loops from I.	30 6 1887
III.	1 7 1887	,, II.	7 7 1887
IV.	14 7 1887	,, III.	23 7 1887
V.	25 7 1887	,, IV.	17 8 1887
VI.	26 8 1887	,, V.	1 10 1887
VII.	3 10 1887	1 needle-loop from VI.	7 10 1887
VIII.	7 10 1887	1 needle-point from VII.	17 10 1887
IX.	17 10 1887	,, VIII.	29 10 1887
X.	7 11 1887	,, IX.	30 11 1887
XI.	1 12 1887	,, X.	15 12 1887
XII.	16 12 1887	,, XI.	13 1 1888
XIII.	28 1 1888	,, XII.	20 2 1888
XIV.	29 2 1888	,, XIII.	5 4 1888
XV.	7 4 1888	,, XIV.	27 4 1888
XVI.	30 4 1888	,, XV.	10 5 1888
XVII.	12 5 1888	,, XVI.	26 5 1888
XVIII.	19 7 1888	,, XVII.	3 9 1888
XIX.	3 9 1888	,, XVIII.	1 10 1888
XX.	11 10 1888	,, XIX.	20 11 1888
XXI.	24 11 1888	,, XX.	26 2 1889
XXII.	26 2 1889	,, XXI.	4 5 1889
XXIII.	28 6 1889	,, XXII.	18 10 1889
XXIV.	4 11 1889	,, XXIII.	17 12 1889
XXV.	27 12 1889	,, XXIV.	25 4 1890
XXVI.	16 5 1890	,, XXV.	2 7 1890
XXVII.	15 7 1890	,, XXVI.	30 1 1891
XXVIII.	3 3 1891	,, XXVII.	28 5 1891

The separation from these foreign forms was ultimately effected by enormously diluting one of these nitrifying solutions, and then taking out small portions of this diluted material and introducing each of these portions into separate ammoniacal solutions. In some of these nitrification was established, in others not, whilst amongst those in which nitrification *was* established, some contained organisms which grew upon gelatin, whilst one refused to give any growth on the gelatin at all, although it was seen under the microscope to contain abundantly bacteria of the form shown in the diagram. [Lantern-slide of nitrifying bacillococcus (Frankland).]

These results, which were published in March 1890, were followed in about a month by a communication in the *Annales de l'Institut Pasteur*, by M. Winogradsky, who had also separated a very similar, if not identical, nitrifying organism, and a few months later again a similar separation was made by Mr. Warington.

But these discoveries had not completely unravelled the problem of nitrification, for the organisms separated in these three independent investigations possessed only the property of *converting ammonia into nitrous and not into nitric acid.* The nitrous acid is an intermediate body, which curiously is rarely found excepting in very minute quantities in soil. The changes will be more clearly understood by reference to the chemical equations:—

$$(1)\quad \underset{\text{(Ammonia)}}{NH_3} + \underset{\text{(Oxygen)}}{3O} = \underset{\text{(Water)}}{H_2O} + \underset{\text{(Nitrous Acid)}}{NHO_2}$$

$$(2)\quad \underset{\text{(Nitrous Acid)}}{NHO_2} + O = \underset{\text{(Nitric Acid)}}{NHO_3}$$

The organisms separated by Winogradsky, by Warington, and by myself, possessed only the property of effecting the first of these changes, they were absolutely destitute of the power of bringing about the second.

Now, the curious thing is that the first of these changes is by far the most difficult to accomplish by *purely chemical means*, whilst the second can be brought about with the greatest facility. [Demonstration of addition of acid permanganate to solution of ammonium sulphate, colour not discharged.] [Demonstration of addition of acid permanganate to solution of potassium nitrite, colour discharged.]

Thus the potassium permanganate has no action on the ammonia, whilst the nitrite it oxidizes to nitrate.

In order to bring about the first change, we have to employ one of the most powerful oxidizing agents known to chemists, viz. ozone. [Demonstration: ozone from a Siemens tube was passed through strong solution of ammonia; the production of nitrous and nitric acids was exhibited by the formation of white fumes, as well as by the sulphanilic acid and diphenylamine tests.]

We thus see that the power of oxidation possessed by our nitrifying organism is altogether unique, and does not find its parallel amongst purely chemical agents of oxidation. *But how then is the nitric acid found in the soil produced, when these organisms yield only nitrous acid?*

At the time when I found that the organism which I had separated produced nitrous acid exclusively, I pointed out that it was doubtless explicable on one of two hypotheses: (1) that nitrous and nitric acids are produced by totally distinct organisms; or (2) that the same organism produces the one or the other according to the conditions under which it is growing.

More recent researches of Winogradsky have shown that the first of these two alternative hypotheses is the correct one, for, by making cultivations of soil in a solution containing nitrous acid and no ammonia, Winogradsky has succeeded in isolating a micro-organism which possesses the power of converting nitrous acid into nitric acid, but has no power of attacking ammonia. [Lantern-slide of nitric ferment (Winogradsky).]

This second organism or *nitric ferment*, as we may call it, resembles in its activity the purely chemical oxidizing agent—*potassium permanganate*—which, as we have seen, has no action on ammonia, but readily converts nitrous into nitric acid.

The process of nitrification in the soil now becomes intelligible in its entirety. It is the work of two independent organisms, the first of which converts ammonia into nitrous acid, whilst the second transforms into nitric acid the nitrous acid produced by the first.

There is a point in connection with the distribution of nitric acid in nature which is exceedingly remarkable, and which forces itself upon the attention of every student of the process of nitrification. Although nitric acid is generally so scantily present in the soil, there is one notable exception to this rule, for in the rainless districts of Chili and Peru there are found immense deposits of nitrate of soda, or Chili-saltpetre, as it is called, which would appear to represent the result of a gigantic nitrification process in some previous period of the earth's history. The vast quantities of this material which occur in these regions of South America can be gathered from the fact that its exportation has for years been going on at the rate indicated by the following figures:—During the first six months of 1890 there were brought to the United Kingdom 90,000 tons, and to the European continent 480,000 tons.

From the presence of such altogether enormous quantities, one is almost tempted to hazard the suggestion that in this particular region of the earth, under some special circumstances of which we know nothing, the nitrifying organisms must have been endowed then and there with very much greater powers than they possess to-day, and it is particularly noteworthy that in a recent examination of soils from nearly all parts of the earth, one coming from Quito, and therefore not far distant from these nitrate fields, was found to possess the power of nitrification in a degree far beyond that exhibited by any other soil hitherto experimented with. Is it not possible, perhaps, that we have in these vigorous nitrifying organisms of the soil of Quito, the not altogether unworthy descendants of the Cyclopean race of nitrifying bacteria, which must have built up the nitrate wealth of Chili and Peru, and thus countless ages ago founded the fortunes of our nitrate kings of to-day?

But these nitrifying organisms have also assisted in teaching us a highly important lesson in connection with the maintenance of life.

The facts which I have already referred to concerning the multiplication of micro-organisms in distilled water, and the continuation of the nitrification-process over a period of four years in purely mineral solutions, are strong presumptive evidence in favour of these bacteria being able to gain a livelihood in the entire absence of organic food-stuffs. I refrained, however, from promulgating such a revolutionary doctrine until I should have had an opportunity of repeating these experiments with materials in which the absence of even the merest traces of organic matter had been assured, for, as chemists well know, even distilled water may contain traces of organic matter.

Such a rigid proof as I had contemplated has, however, in the meantime been attempted by M. Winogradsky, also in connection with his experiments on nitrification, and he has indeed found that the nitrifying organisms flourish, multiply, and actually build up living protoplasm in a solution from which organic matter has been most rigorously excluded. Now this living protoplasm in the experiments in question must have been elaborated by these bacteria from carbonic acid as the source of the protoplasmic carbon, and from ammonia and nitrous or nitric acids as the source of the protoplasmic nitrogen. If these experiments are correct, and they were undoubtedly performed with great skill and much caution, they are subversive of one of the fundamental principles of vegetable physiology, which denies to all living structures, save those of green plants alone, the power of building up protoplasm from such simple materials.

I had occasion to mention in connection with these nitrifying organisms that they refuse to grow on the ordinary solid cultivating media employed by bacteriologists, a fact which presents a great obstacle to their isolation in a state of purity, for it is just by means of these solid culture media that micro-organisms are most easily obtained in the pure state.

This difficulty has, however, been overcome in a most ingenious manner, originally devised by Prof. Kühne, in which the solid medium is wholly composed of mineral ingredients, the jelly-like consistency being obtained by means of silica. [Demonstration of preparation of silica-jelly, consisting of ammonia sulphate, potassium phosphate, magnesium sulphate, calcium chloride, magnesium carbonate, and dialyzed silicic acid.]

Fixation of Free Nitrogen by Plants.

But whilst the study of the bacteria giving rise to nitrification has thus led to the subversion of what was regarded as a firmly established principle of vegetable physiology (viz. *the incapacity of any but green plants to utilize carbonic acid in the elaboration of protoplasm*), the same science has received another shock, of perhaps equal if not greater violence, through researches which have been carried on with other micro-organisms flourishing in the soil.

For nearly a century past agricultural chemists and vegetable physiologists have been debating as to whether the free nitrogen of our atmosphere can be assimilated or utilized as food by plants. This question was answered in the negative by Boussingault about fifty years since; the problem was again attacked by Lawes, Gilbert, and Pugh about thirty years ago, and *their* answer was also in the negative. In the course, however, of their continuous experiments on crops, Lawes and Gilbert have frequently pointed out that whilst the nitrogen in most crops can be accounted for by the combined nitrogen supplied to the land in the form of manures and in rain water, yet in particular *leguminous* crops, such as peas, beans, vetches, and the like, there is an excess of nitrogen which cannot be accounted for as being derived from these obvious sources. The origin of this excess of nitrogen in these particular crops they admitted could not be explained by any of the orthodox canons of the vegetable physiology of the time. The whole question of the fixation of atmospheric nitrogen by plants was again raised in 1876 by a very radical philosopher, in the person of M. Berthelot, whilst the most conclusive experiments were made on this subject by two German investigators, Prof. Hellriegel and Dr. Wilfarth, who have not only shown that this excess of nitrogen in leguminous crops is obtained from the atmosphere, but also that this assimilation of free nitrogen is dependent upon the presence of certain bacteria flourishing in and around the roots of these plants, for when these same plants are cultivated in sterile soil the fixation of atmospheric nitrogen does not take place. Moreover, the presence of these microbes in the soil occasions the formation of peculiar swellings or tuberosities on the roots of these plants, and these tuberosities, which are not formed in sterile soil, are found to be remarkably rich in nitrogen, and swarming with bacteria. [Lantern-slide of nodules on roots of sainfoin (Lawes and Gilbert).]

Extremely important and instructive in this respect are the experiments of Prof. Nobbe, who has not only confirmed the results mentioned, but has endeavoured to investigate the particular bacteria which bring about these important changes, and he has indeed succeeded in showing that in many cases each particular leguminous plant is provided with its particular micro-organism which leads to its fixation of free nitrogen. Thus he found that if pure cultivations of the bacteria obtained from a pea-tubercle were applied to a pea plant there was a more abundant fixation of atmospheric nitrogen by this pea-plant than if it was supplied with pure cultures of the microbes from the tubercles of a lupin or a robinia; whilst similarly the robinia was more beneficially affected by the application of pure cultures from robinia-tubercles than by those from either pea-tubercles or lupin-tubercles. [Lantern-slides exhibiting Nobbe's experiments on pea and robinia.]

This subject of the source of nitrogen in leguminous plants has again been taken up by Sir John Lawes and Dr. Gilbert at Rothamsted, and their recent results fully confirm the observations of these foreign investigators that it is partially derived from the free atmospheric nitrogen through the agency of bacteria in the soil.

To micro-organisms again, then, we must ascribe the accomplishment of this highly important chemical change going on in the soil, although it has not hitherto been so fully illuminated as the process of nitrification.

Selective Action of Micro-organisms.

Any of the ordinary plants and animals with which we are familiar may be regarded as analytical machines, and we ourselves, without any knowledge of chemistry, are constantly performing analytical tests; thus we can all distinguish between sugar and salt by the taste, between ammonia and vinegar by the smell, whilst by a more elaborate investigation we distinguish, for instance, between the milk supplied from two different dairies by ascertaining on which we or our children thrive best. In fact, such analytical or selective operations are amongst the first vital phenomena exhibited by an organism on coming into this world. It is, however, particularly surprising to find this analytic or distinguishing capacity developed in an extraordinarily high degree amongst micro-organisms. From the power which we have seen that some possess of flourishing on the extremely thin diet to be found in distilled water, we should be rather disposed to think that caprice would be the very last failing with which they would be chargeable. As a matter of fact, however, the perfectly unfathomable and inscrutable caprice of these minute creatures is amongst the first things with which the student of bacteriological phenomena becomes impressed. Let me call your attention to a striking example of this which I have recently investigated.

I have here two substances, which have the greatest similarity:—

	MANNITE.	DULCITE.
Occurrence.	Numerous plant-juices ...	Ditto, but less frequently.
Taste.	Sweet	Ditto, but less so.
Melts.	166° C.	188° C.
Crystalline form.	Large rhombic prisms	Large monoclinic prisms.

Not only, however, do these two substances possess such a strong external resemblance to each other, but in their chemical behaviour also they are so closely allied that one formula has to do duty for both of them, for so slight is the difference in the manner in which their component atoms are arranged that chemists have not yet been able with certainty to ascertain in what that difference consists. Under these circumstances it would have been anticipated that bacteria would be quite indifferent as to which of these two substances was presented to them, and that they would regard either both or neither as acceptable. But such is by no means the case; some micro-organisms, like ordinary yeast, have *no action upon either*, whilst *others will attack mannite, leaving dulcite untouched, others again, being less discriminating, attack both*: representatives of a fourth possible class *which would act upon dulcite but not upon mannite* are as yet undiscovered. [Lantern-slide and plate-culture of *B. ethaceticus.*]

This bacillus, I have recently shown, has the property of breaking down the mannite molecule into alcohol, acetic acid, carbonic anhydride, and hydrogen, but leaves the dulcite molecule untouched.

More recently I have, in conjunction with my late assistant, Mr. Frew, succeeded in obtaining a micro-organism which decomposes both mannite and dulcite into alcohol, acetic and succinic acids, carbonic anhydride, and hydrogen. [Lantern-slide and plate-culture of *B. ethacetosuccinicus.*]

Optically Active Substances.

But these are by no means the ultimate limits to which the selective or discriminating powers of micro-organisms can be pushed, for although mannite and dulcite are extremely similar substances, they are not chemically identical. We are acquainted, however, with substances which, though chemically identical, are different in respect of certain physical properties, and are hence known as *physical isomers*. It is in explanation of this physical isomerism that one of the most beautiful of chemical theories was propounded by Lebel and Van 't Hoff in 1874, and which remains unsupplanted to the present day.

This theory depends upon taking into consideration the dissymmetry of the molecule which is occasioned by the presence in it of a carbon-atom which is combined with four different atoms or groups of atoms, and is most easily intelligible from an inspection of these two models. [Demonstration of tetrahedral models of asymmetric carbon-atom.]

This molecular dissymmetry is specially exhibited in the crystalline form of such substances, and in their action upon polarized light.

The molecule arranged according to the one pattern has the property of turning the plane of polarization in one direction, whilst the molecule arranged according to the other pattern has invariably the property of tnrning the plane through precisely the same angle in the opposite direction. The molecular dissymmetry ceases when two such molecules combine together, the resulting molecule having no action on polarized light at all.

The interest of these phenomena in connection with micro-organisms lies in the fact that they are sometimes possessed of the power of discriminating between these physical isomers. Although this remarkable property was demonstrated years ago by Pasteur in respect of the tartaric acids, it has only comparatively rarely been taken advantage of. Recently, however, chemical science has been enriched in several instances by successfully directing the energies of micro-organisms in such work of discrimination.

During the past few years no chemical researches have commanded more interest, both on account of their theoretic importance and the fertility of resource exhibited in their execution, than those of Emil Fischer's, which have led to the artificial preparation in the laboratory of several of the various forms of sugar occurring in nature, as well as of other sugars not hitherto discovered amongst the products of the animal or vegetable kingdoms. The natural sugars are all of them bodies with dissymmetric molecules, powerfully affecting the beam of polarized light, but when prepared artificially they are without action on polarized light, because in the artificial product the left-handed and right-handed molecules are present in equal numbers, the molecules of the one neutralizing the molecules of the other, and thus giving rise to a mixture which does not affect the polarized beam either way. By the action of micro-organisms, however, on such an inactive mixture, the one set of molecules is searched out by the microbes and decomposed, leaving the other set of molecules untouched, and the latter now exhibit their specific action on polarized light, an active sugar being thus obtained.

The most suitable micro-organisms to let loose, so to speak, on such an inactive mixture of sugar-molecules, are those of brewers' yeast, which decompose the sugar molecules with formation of alcohol and carbonic anhydride. Their action on these inactive artificial sugars of Fischer's is particularly noteworthy.

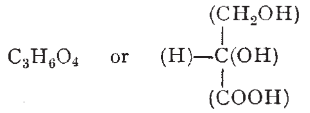
One of the principal artificial sugars prepared by Fischer is called *fructose*; it is inactive, but consists of an equal number of molecules of oppositely active sugars called *lævulose*.

One set of these lævulose-molecules turns the plane of polarization to the right, and we may call them *right-handed lævulose*, whilst the other set of *lævulose-molecules* turns the plane of polarization to the left, and we may call them *left-handed lævulose*.

The left-handed lævulose occurs in nature, whilst the right-handed lævulose, as far as we know, does not. Now, on putting brewers' yeast into a solution of the fructose, the yeast-organisms attack the left-handed lævulose molecules and convert them into alcohol and carbonic anhydride, whilst the right-handed lævulose is left undisturbed. The yeast organisms thus attack that particular form of lævulose of which their ancestors can have had experience in the past, whilst they leave untouched the right-handed lævulose molecules, which, being a new creation of the laboratory, they have no hereditary instinct or capacity to deal with.

This selective power is possessed also by other forms of micro-organisms besides the yeasts, which are indeed only suitable for the separatory decomposition of sugars, and by means of bacterial forms a much greater variety of substances can be attacked in this manner. Thus I have recently found that glyceric acid can be decomposed by the *B. ethaceticus*, to which I have already referred this evening.

This glyceric acid is thus represented by chemists :—



$$C_3H_6O_4 \quad \text{or} \quad \begin{array}{c} (CH_2OH) \\ | \\ (H)\text{—}C(OH) \\ | \\ (COOH) \end{array}$$

and this should, according to Le Bel and Van 't Hoff's theory, be capable of existing in two physically isomeric forms, as easily shown by our models.

The ordinary glyceric acid known to chemists is, however, quite inactive to polarized light, and must consist, therefore, of a combination in equal molecules of a right-handed and left-handed glyceric acid. Now when the *B. ethaceticus* is put into a suitable solution of the calcium salt of this glyceric acid, it multiplies abundantly, and completely consumes the right-handed molecules of the salt, but leaves the left-handed molecules entirely intact, a powerfully active glyceric acid being thus obtained. [Demonstration of the lævorotary power of solution of new zinc glycerate with projection-polariscope.]

A number of derivatives of this new active glyceric acid have recently been prepared in my laboratory :—

Derivatives of Active Glyceric Acid.

Formula.	Specific Rotation. $[\alpha]_D$
$(C_3H_5O_3)_2$ Ba + $2H_2O$	-9°
$(C_3H_5O_3)_2$ Sr + $3H_2O$	-10
$(C_3H_5O_3)_2$ Ca + $2H_2O$	-12
$(C_3H_5O_3)_2$ Cd + $1\frac{1}{2}H_2O$	-14
$(C_3H_5O_3)_2$ Zn + H_2O	-22
$(C_3H_5O_3)_2$ Mg + H_2O	$-18{\cdot}5$
$C_3H_5O_3$ Na	-16
$C_3H_5O_3$ Am	-20
$C_3H_5O_3$ K	-15
$C_3H_5O_3$ Li	$-20{\cdot}5$
$C_3H_5O_3$ Me	$-4{\cdot}8$
$C_3H_5O_3$ Et	$-9{\cdot}2$
$C_3H_5O_3$ Pr (*n*)	$-13{\cdot}0$

Here again, then, chemistry has been enriched by a number of new compounds, which we owe entirely to the unaccountable caprice of this micro-organism.

Individuality of Micro-organisms.

Although micro-organisms are thus becoming more and more indispensable reagents in the chemical laboratory, essential as they are for the production of many bodies, it is always necessary to bear in mind that by virtue of their vitality their nature is infinitely more complex than that of any inanimate chemicals which we are accustomed to employ. In a chemically pure substance we believe that one molecule is just like another, and hence we expect perfect uniformity of behaviour in the molecules of such a pure substance under prescribed conditions. In a pure cultivation of a particular species of micro-organism, however, we must not expect such rigid uniformity of behaviour from each of the individual organisms making up such a cultivation, for there may be and frequently are great differences amongst them; in fact, each member of such a pure culture is endowed with a more or less marked individuality of its own, and these possible variations have to be taken into consideration by those who wish to turn their energies to account. In fact, experimenting with micro-organisms partakes rather of the nature of legislating for a community than of directing the inanimate energies of chemical molecules. Thus frequently the past history of a group of micro-organisms has to be taken into account in dealing with them, for their tendencies may have become greatly modified by the experiences of their ancestors.

Of this I will give you an instance which has recently come under my observation :—

Here is a bacillus, which has the property of fermenting calcium citrate; I have found that it can go on exerting this power for years. On submitting this fermenting liquid to plate-cultivation, we obtain the appearances which you see here. [Lantern-demonstration of plate-culture of bacillus which ferments calcium citrate.]

If one of these colonies be transferred to a sterile solution of calcium citrate, it invariably fails to set up a fermentation of the latter, the bacillus having thus by mere passage through the gelatin-medium lost its power to produce this effect. If, however, we take another similar colony and put it into a solution of broth containing calcium citrate, fermentation takes place; on now inoculating from this to a weaker solution of broth containing calcium citrate, this also is put into fermentation, and by proceeding in this manner we may ultimately set up fermentation in a calcium citrate solution which absolutely refused to be fermented when the bacilli were taken directly from the gelatin-plate.

Phenomena of this kind clearly indicate that there may be around us numerous forms of micro-organisms of the potentiality of which we are still quite ignorant. Thus, if we were only acquainted with the bacilli I have just referred to from gelatin cultures, we should be quite unaware of their power to excite this fermentation of calcium citrate, which we have only been enabled to bring about by pursuing the complicated system of cultivation I have indicated. It is surely exceedingly probable, therefore, that many of the micro-organisms with which we are already acquainted may be possessed of numerous important properties which are lying dormant until brought into activity by suitable cultivation.

This power of modifying the characters of bacteria by cultivation is, I venture to think, of the highest importance in connection with the problems of evolution, for in these lowly forms of life, in which, under favourable circumstances, generation succeeds generation in a period of as little as 20 minutes, it should be possible through the agency of selection to effect metamorphoses, both of morphology and physiology, which would take ages in the case of more highly organized beings to bring about.

We hear much about the possibility of altering the human race through training from the enthusiastic apostles of education, but even the most sanguine cannot promise that any striking changes will be effected within several generations, so that such predictions cannot be tested until long after these reformers have passed away. In the case of micro-organisms, however, we can study the effect of educational systems consequentially pursued through thousands of generations within even that short span of life which is allotted to us here.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Dr. Peile, Master of Christ's College, has been re-elected Vice-Chancellor for the ensuing academical year.

The examination for the Diploma in Public Health will begin on October 4. Candidates are to send their names to the Registrary by September 27.

Prof. Roy announces a special course in Bacteriology, to be given during the long vacation by Mr. Adami, Mr. Kanthack (one of the Leprosy Commissioners), and Dr. Lloyd Jones, beginning on July 8. It is especially intended for candidates, not necessarily members of the University, for the Diploma in Public Health.

An elaborate scheme for the proposed Mechanical Sciences Tripos has been prepared by a special Syndicate, and appears in the *University Reporter* for May 31. The Tripos follows the main lines of the Natural Sciences Tripos, and seems to be free from the objections which have proved fatal to former schemes.

It is understood that the persons on whom honorary degrees are to be conferred on June 11, in connection with the Chancellor's inauguration, have been for the most part nominated by his Grace. This will perhaps account for the political character of the list, which is, however, partially relieved by the presence on it of General R. Strachey, and Mr. G. W. Hill, late of the office of the *American Ephemeris*, and known among astronomers for his fine work on the lunar theory. Five of the honorary graduates are Fellows of the Royal Society.

The University College of Wales, Aberystwyth, has been admitted to the privileges of a College affiliated to the University. The Mason College of Science, Birmingham, has been associated with the Local Lectures Syndicate in the work of University Extension.

Dr. W. Howship Dickinson, Dr. Bradbury, and Dr. J. F. Payne have been appointed Examiners in Medicine, Dr. W. S. Playfair and Dr. Griffith Examiners in Midwifery, and Messrs. Herbert Page, Frederick Treves, and Howard Marsh Examiners in Surgery.

Notice of opposition to the appointment of Sir R. S. Ball to the Directorship of the Observatory has been given. The grounds stated are that the duties of the Professorship of Geometry and Astronomy should occupy the whole time of the Professor, while the energies of the Director, in view of the recent developments of astronomical science, should be entirely devoted to the work of the Observatory. It is also held to be unwise in these circumstances to refuse the munificent offer of Mrs. Adams to provide £10,000 for the endowment of a separate Director.

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, May 19.—"On the Changes produced by Magnetization in the Length of Iron and other Wires carrying Currents." By Shelford Bidwell, M.A., LL.B., F.R.S.

The changes of length attending the magnetization of rods or wires of iron and other magnetic metals which were first noticed by Joule in 1841, and have in recent years formed the subject of many experiments by the author, have been found to be related to several other phenomena of magnetism. Maxwell has suggested that they sufficiently account for the twist which is produced in an iron wire when magnetized circularly and longitudinally at the same time. The resultant lines of magnetization, as he points out, take a spiral form; the iron expands in the direction of the lines of magnetization, and thus the wire becomes twisted. Prof. G. Wiedemann, however, to whom the discovery of the magnetic twist is due, appears not to be satisfied with this explanation, believing the effect to be caused by unequal molecular friction.

The subject of magnetic twists has been very fully and carefully investigated by Prof. C. G. Knott, and in a paper published last year in the Transactions of the Royal Society of Edinburgh (vol. xxxvi., Part II., p. 485) he indicates many details in which the phenomena of twist closely correspond with those of elongation and retraction. Assuming their essential identity, and noting that "an increased current along the wire affects the points of vanishing twist in a manner opposite to that in which an increased tension affects it," Prof. Knott is "inclined to conclude that the pure strain effects of these influences are of an opposite character." Now, since the magnetic elongation of an iron wire is known to be diminished by tension, the remark above quoted amounts to a prediction that in an iron wire carrying a current the magnetic elongation would be increased. "We know nothing so far," Prof. Knott observes, "regarding the changes of length when an iron wire *carrying a current* is subjected to longitudinal magnetizing forces"; and it was with the object of acquiring some information on this point, and testing Prof. Knott's prediction, that the experiments described in the present paper were undertaken. The results show that it was amply verified, and thus Maxwell's explanation of the twist receives still further corroboration.

The apparatus used and the methods of observation were the same as those described in former papers. Each specimen of wire examined was 10 cm. long, and the indications of the instrument were read to one ten-millionth part of the length.

The wire first used was of soft commercial annealed iron, 0·75 mm. in diameter. The changes of length which it exhibited under the influence of magnetizing forces gradually increased from 13 to 315 C.G.S. units are indicated in the second column of Table I., in which the unit is one-millionth of a centimetre or one ten-millionth of the effective length of the wire.

The experiment described in the last paragraph was repeated while a current of 1 ampere was passing through the wire, the several magnetizing forces employed being made as nearly as possible the same as before by inserting the same resistances successively in the circuit. The results appear in the third column of Table I., and show that the maximum elongation had risen from 11·5 to 14·5 ten-millionths, while the decrement in a field of 315 had fallen from 22·5 to about 17·5.

The current through the iron wire was then increased, by an alteration of the rheostat, to 2 amperes, and, as appears in the last column of the table, there was again a marked increase of the maximum elongation, and decrease of the retraction in a field of 315.